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Abstract

A paper recently published in the journal *Tobacco Control* purports to show that the implementation of a smoking prohibition in Delaware had no statistically significant effect on the revenues of three gaming facilities in that state. After undertaking a thorough analysis of the data, I find that the smoke-free law *did* affect revenues from gaming in Delaware. Total gaming revenues are estimated to have declined by at approximately $6½ million per month after the implementation of Delaware's Clean Indoor Air Law. This represents a loss nearly 13% relative to average monthly revenues in the year preceding the smoking ban.

*The views expressed in this paper are those of the author and do not necessarily represent the official positions of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

Smoke-Free Law *Did* Affect Revenue From Gaming in Delaware

A paper recently published in *Tobacco Control,* Mandel et al. (2005), purports to show that the implementation of a smoking prohibition in Delaware had no statistically significant effect on the revenues of three gaming facilities in that state.[1] The stated purpose of the article is to refute the contention of the gaming industry that smoking bans pose a threat to their business: "These results reject the argument that smoke-free laws hurt revenues from gaming."

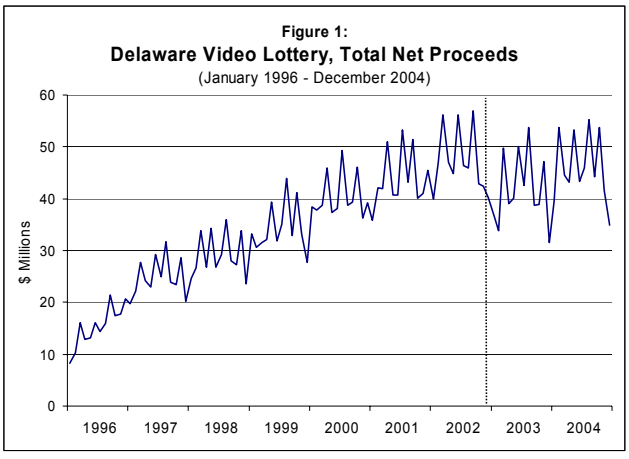
I have examined the data used in that study and conclude that the reported finding is incorrect. Several methodological issues about the accuracy and robustness of the results are evident in the original paper. A subsequently published "Erratum" corrected for some of these problems, but retained the conclusion of the original paper.[2] Nevertheless, methodological flaws remain, and my analysis of the data shows that the smoke-free law *did* affect revenues from gaming in Delaware. Total gaming revenues are estimated to have declined by nearly $6½ million per month after the implementation of Delaware's Clean Indoor Air Law

The data used in my analysis are reported in full in an appendix to this paper.

1. Data and Methods

The data of interest are the total net proceeds of three gaming facilities at racetracks in Delaware offering "slot machine-like video lottery terminals." Data on the total number of terminals in these three locations are also included in the analysis. The data are publicly available from The Delaware Lottery.[3]

Figure 1 presents the data on total video gaming revenues (net proceeds) at the three Delaware "racinos." The vertical line represents the date that the Delaware Clean Indoor Air Law was implemented. A casual inspection of the data shows that there was a decline in net proceeds at Delaware racinos following the implementation of the smokefree law in December 2002. After correction for a data coding error, the "Erratum" of Glantz and Alamar shows this as a negative point estimate. Citing heteroskedasticity, however, they conclude that a weighted least-squares estimate of the effect is not significantly different from zero—retaining the original finding of Mandel et al.



[1] Mandel, Alamar, and Glantz (2005).

[2] Glantz and Alamar (2005).

[3] Delaware Lottery (2005).

To adjust for inflation, Mandel et al. reports that the revenue data were "inflated to May 2004 dollars." After using the CPI-U to make this adjustment, I superimposed replicated data series over the figures presented in the published paper, verifying the inflation-adjustment and confirming the accuracy of the replicated data for total revenues and the number of video lottery machines in operation.

To control for economic activity, the authors use quarterly personal income for the Mideast Region of the U.S. They report that "the data were interpolated to create monthly estimates." Although their method was not described in detail, a simple linear interpolation appears to replicate the authors' procedure.

Note that the data on personal income data are nominal, so it is superfluous to control for inflation using CPI data *and* include personal income as an explanatory variable in the regression. Further analysis of the regression results suggests that this consideration is relatively unimportant: with both a linear and quadratic time variables to control for trend, the income variable in the regressions of Mandel et al. plays the role of an omitted constant term (discussed in more detail below). Regarding the "Erratum" of Glantz and Alamar, replications suggest that the data were adjusted to December 2005 prices, and that the income variable was also deflated to be expressed in real terms. The results reported here also adopt those conventions.

Seasonal effects were estimated in Mandel et al.using a rather unorthodox approach of employing quarterly dummy variables to account for monthly seasonal patterns.[4] The data presented in Figure 1 show that revenues are indeed low in the winter months, but also that revenues in the spring and summer months tend to be considerably higher than average. The consideration of seasonal effects in Mandel et al. fails to adequately account for these evident regularities. The authors report that "only winter was found to be significant, thus only the results with winter are reported." However, the significance of a particular seasonal dummy variable depends on the specification being considered. It is invalid to discard specific seasonal dummy variables based on individual significance tests from a particular regression. And in fact, I find that additional seasonal effects are indeed significant.

2. Results

Table 1 reports the results of ordinary least squares regressions corresponding to those reported in the "Erratum" of Glantz and Alamar, using currently available data. The regressions include a time-trend, a squared time-trend, the number of video gaming machines in service, personal income for the Mideast region, and a dummy variable for w*inter*. The first regression has inflation-adjusted total revenues as the dependent variable; the second uses average revenues per machine. The focus of the analysis is on the variable P_{law}, a dummy

[4] The use of quarterly (rather than monthly) dummy variables presumably reflects a desire to maintain adequate degrees of freedom. Instead of using dummy variables corresponding to calendar quarters, however, the authors use the unusual convention of defining quarters by season. For example the variable *Winter* takes on a value of one in the months of December, January, and February and zero otherwise.

variable representing the implementation of the smoke-free ordinance. The coefficient on P_{law} is negative in both equations. In the case of total revenues, the estimate is significant.

TABLE 1: Ordinary Least Squares Regression Results

	Total revenues ($million)			Average revenue per machine ($/machine)		
Variable	**Estimate**	**SE**	**p-Value**	**Estimate**	**SE**	**p-Value**
P_{law}	-5.601	2.746	0.044	-1158.05	745.12	0.124
Time	0.555	0.133	<0.001	95.46	36.14	0.010
$Time^2$	-0.003	0.001	0.003	-0.312	0.277	0.262
Machines	0.002	0.002	0.334	-2.763	0.434	<0.001
Income ($trillion)	10.376	1.738	<0.001	10782.43	471.61	<0.001
Winter	-4.344	1.160	<0.001	-1353.20	314.80	<0.001
N	101			101		
R^2	0.805			0.639		

Glantz and Alamar report that the residuals from the total revenue equation display heteroskedasticity. I do not find evidence of that this problem is significant—a properly specified White's test fails to reject the null hypothesis of homoskedasticity ($p = 0.13$). Nevertheless, a visual inspection of the residuals does suggest the presence of some mild heteroskedasticity. The authors' method of correction for this potential problem, however, is suspect. Glantz and Alamar report estimates from a weighted least squares regression, using the inverse of the number of video lottery machines as a weight.

In the presence of heteroskedasticity, coefficient estimates are inefficient, but unbiased. But in the weighted least-squares estimates reported by Glantz and Alamar, the point estimate of the coefficient on P_{law} is considerably different from the ordinary least-squares estimate. This alone should give one pause in accepting the weighted least-squares estimate. Moreover, the weighted least-squares estimate reported in Glantz and Alamar results in a considerable reduction in the R^2 of the regression.[5]

The pattern of residuals suggests that evidence of heteroskedasticity is concentrated in the data for 1996—the first year of the sample. Two of the three Delaware racinos opened at the beginning of 1996, while the third did not begin operations until August 1996. Consequently, there is a sharp increase in the number of video lottery machines in operation during the year, which accounts for the dramatic effect of the weighting scheme employed by

[5] Note that the weighted least-squares regression equation can be interpreted as a restricted version of the average revenue per machine specification. In particular, *time/machine, time^2/machine*, *income/machine* and a constant (*machine/machine*) control for the trend component, while P_{law}/*machine* becomes the policy variable. In this specification, evaluating the significance of a negative coefficient on the policy variable can be interpreted as a test of the joint hypothesis that average revenues declined following the implementation of the smokefree law *and* that average revenues per machine subsequently increased in response to a large expansion in the number of machines at the beginning of 2004.

Glantz and Alamar. If observations from 1996 are dropped from the sample, there is clearly no evidence of heteroskedasticity (p = 0.25), and the coefficient estimates for both the ordinary least squares and weighted least squares specifications are the same: For P_{law}, the OLS estimate is -7.82 (p = 0.012) and the WLS estimate is -7.81 (p = 0.041).

A more parsimonious approach to controlling for heteroskedasticity is to employ methods for calculating a heteroskedasticity-consistent covariance matrix. Using the method of Newey and West (1987), I found that the point estimate for the coefficient on P_{law} reported in Table 1 is associated with a corrected standard error of 2.121 (p = 0.010).

Heteroskedasticity is not the only problem plaguing the residuals from the regressions reported in Table 1. Significant serial correlation is also present. Table 2 reports estimates of regressions including an AR(1) specification for the residuals. Newey-West HAC-consistent estimates are used to calculate standard errors, adjusting for any heteroskedasticity and higher-order serial correlation. The AR coefficients are highly significant in both the total revenues and average revenue equations. The coefficients on P_{law} are negative and highly significant in both regressions.

TABLE 2: Regression Results with Adjustment for AR(1) Residuals

	Total revenues ($million)			Average revenue per machine ($/machine)		
Variable	**Estimate**	**SE***	**p-Value**	**Estimate**	**SE***	**p-Value**
P_{law}	-6.088	1.982	0.003	-1433.92	425.80	0.001
Time	0.540	0.094	<0.001	80.33	36.14	0.029
$Time^2$	-0.003	0.001	<0.001	-0.159	0.216	0.463
Machines	0.002	0.001	0.182	-2.768	0.361	<0.001
Income ($trillion)	10.546	1.404	<0.001	10957.57	264.80	<0.001
Winter	-4.215	0.765	<0.001	-1198.72	201.53	<0.001
AR(1)	-0.273	0.065	<0.001	-0.226	0.070	0.002
N	100			100		
R^2	0.807			0.678		

* Newey-West HAC standard errors.

An important shortcoming of the model specifications considered thus far is the failure to control adequately for seasonal variation. Table 3 shows the results of monthly model that includes a constant term plus dummy variables for w*inter*, s*pring,* and s*ummer*. The data set used for these regressions has also been extended to include observations through December 2004.

TABLE 3: Regression Results Using a Full Seasonal Specification
(Including an extended sample period)

	Total revenues ($million)			Average revenue per machine ($/machine)		
Variable	**Estimate**	**SE***	**p-Value**	**Estimate**	**SE***	**p-Value**
P_{law}	-6.487	1.663	<0.001	-1567.29	348.92	<0.001
Time	0.638	0.117	<0.001	85.36	22.28	<0.001
$Time^2$	-0.003	0.001	<0.001	-0.166	0.149	0.269
Machines	0.002	0.001	0.049	-2.728	0.284	<0.001
Income ($trillion)	-11.581	18.263	0.528	9493.88	3535.54	0.009
Constant	30.618	26.563	0.252	1506.59	5143.92	0.770
Winter	-2.549	0.947	0.008	-614.83	242.35	0.013
Spring	2.326	0.829	0.006	892.90	235.64	<0.001
Summer	3.110	0.864	<0.001	908.06	228.97	<0.001
AR(1)	-0.333	0.058	<0.001	-0.304	0.064	<0.001
N	107			107		
R^2	0.818			0.743		

* Newey-West HAC standard errors.

The results show that Delaware racino revenues tend to be significantly higher in the spring and summer, and lower in winter (relative to the fall). These findings clearly refute the contention that only the seasonal effects of winter are relevant.

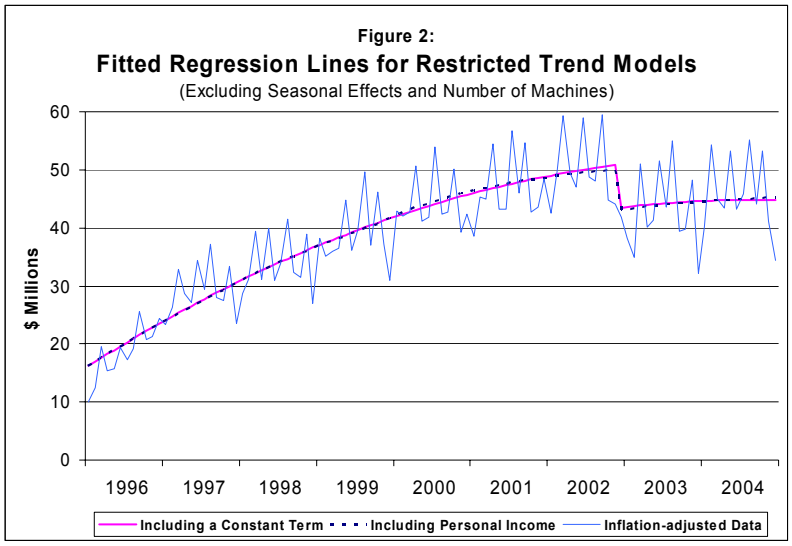
More importantly, the regression results reported in Table 3 confirm that the coefficient on the smoking-ban dummy variable is significantly negative. In the regression for total revenues, the point estimate for the P_{law} coefficient suggests losses of nearly $6½ million per month. This figure represents a revenue loss of nearly 13 percent compared to the year preceding the smoking ban.[6]

Similar results were obtained with a complete set of monthly dummy variables included in the regression. The coefficients on P_{law} were found to be –6.54 ($p<0.001$) in the total revenue regression ($R^2=0.846$) and –1583 ($p<0.001$) in the average revenue regression ($R^2=0.777$).

In the regression results reported in Table 3, the coefficients on *income* are not statistically significant, nor are the constant terms. However, these two terms were found to be jointly significant, suggesting that the *income* variable in the MAG regressions primarily plays the role of an omitted constant term. Figure 2 demonstrates this feature by comparing the fitted values from two scaled-down regression equations that include only the linear and quadratic trend variables, along with the smoking-ban dummy variable (seasonal effects and number of machines are excluded). One regression included a constant term, while the other

[6] This finding is consistent with reports from the operators of the racinos. For example, Dover Downs (2004) attributed a revenue loss of 11 percent in 2003 to the Delaware smoking ban.

included the *income* variable. There is clearly little difference between the two. The regression with a constant term has an R^2 of 0.763, while the regression including income has an R^2 equal to 0.762. The coefficient on P_{law} was significant in each of these regressions. The coefficient values were -7.44 (p=.007) in the equation with a constant term and -6.94 (p=.011) in the equation that included *Income*.



3. Conclusion

I find that the smoke-free law in Delaware *did* affect revenue from gaming in Delaware. Statistically significant point estimates suggest that the Delaware Clean Indoor Air Law is associated with a decline of approximately $6½ million per month in total inflation-adjusted revenues at Delaware "racinos." This represents a drop of nearly 13 percent relative to average revenues in the year preceding the smoking ban. The public health benefits of smokefree laws should be weighed against these (and other, similar) economic costs.

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Data Appendix

The following table reports the data used in the analysis. The variables are:

Income: Total Personal Income, Mideast Region, millions of dollars (seasonally adjusted annual rate). Source: Bureau of Economic Analysis. Quarterly data were interpolated to monthly figures aligning the quarterly data points with the mid-month of the quarter, and allocating the change between quarterly observations equally to the two intervening months.

CPI-U: Consumer Price Index, All Urban Consumers (CPI-U, 1982-1984=100). All items, seasonally adjusted. Source: Bureau of Labor Statistics. In the analysis, the data are rebased by dividing the series by the value of the CPI-U for December 2004.

Revenues: Net proceeds from Video Lottery terminals at Delaware Park, Dover Downs, and Harrington. Source: Delaware Lottery.

Machines: Total number of Video Lottery terminals at Delaware Park, Dover Downs, and Harrington. Source: Delaware Lottery.

	Income	CPI-U	Revenues	Machines
1996-Jan	1221487	154.7	8269900	1215
1996-Feb	1227797	155.0	10280900	1215
1996-Mar	1234107	155.5	16123800	1215
1996-Apr	1240418	156.1	12787900	1215
1996-May	1246728	156.4	13091200	1270
1996-Jun	1250421	156.7	16102700	1287
1996-Jul	1254114	157.0	14449600	1413
1996-Aug	1257807	157.2	15985100	2047
1996-Sep	1263814	157.7	21406400	2025
1996-Oct	1269822	158.2	17450600	2498
1996-Nov	1275829	158.7	17813800	2498
1996-Dec	1281663	159.1	20616500	2498
1997-Jan	1287496	159.4	19735800	2498
1997-Feb	1293330	159.7	22198300	2498
1997-Mar	1297449	159.8	27742300	2580
1997-Apr	1301567	159.9	24251800	2580
1997-May	1305686	159.9	22955000	2580
1997-Jun	1312509	160.2	29201900	2580
1997-Jul	1319332	160.4	24921700	2580
1997-Aug	1326155	160.8	31726100	2580
1997-Sep	1334740	161.2	23926500	2580
1997-Oct	1343326	161.5	23475600	2580
1997-Nov	1351911	161.7	28620100	2580
1997-Dec	1359324	161.8	20150000	2580

	Income	CPI-U	Revenues	Machines
1998-Jan	1366736	162.0	24618800	2580
1998-Feb	1374149	162.0	26642100	2580
1998-Mar	1382995	162.0	33894100	2580
1998-Apr	1391841	162.2	26722400	2580
1998-May	1400687	162.6	34327500	2702
1998-Jun	1406339	162.8	26717500	2702
1998-Jul	1411992	163.2	29234200	2702
1998-Aug	1417644	163.4	35921400	2727
1998-Sep	1420457	163.5	28074300	2772
1998-Oct	1423270	163.9	27299700	2802
1998-Nov	1426083	164.1	33843700	2806
1998-Dec	1434581	164.4	23525500	2982
1999-Jan	1443078	164.7	33263500	3005
1999-Feb	1451576	164.7	30620100	3044
1999-Mar	1452367	164.8	31460000	3360
1999-Apr	1453158	165.9	32115300	3376
1999-May	1453949	166.0	39384800	3441
1999-Jun	1460519	166.0	31818700	3545
1999-Jul	1467090	166.7	35034000	3899
1999-Aug	1473660	167.1	43891900	3912
1999-Sep	1479060	167.8	32915700	3899
1999-Oct	1484460	168.1	41161600	3913
1999-Nov	1489860	168.4	33185300	3913
1999-Dec	1508159	168.8	27642400	4226
2000-Jan	1526457	169.3	38451800	4226
2000-Feb	1544756	170.0	37764800	4539
2000-Mar	1553406	171.0	38712500	4633
2000-Apr	1562055	170.9	45889200	4633
2000-May	1570705	171.2	37288500	5037
2000-Jun	1577973	172.2	38120900	5037
2000-Jul	1585242	172.7	49307200	5037
2000-Aug	1592510	172.7	38762300	5037
2000-Sep	1599994	173.6	39333300	5151
2000-Oct	1607477	173.9	46142700	5151
2000-Nov	1614961	174.2	36199500	5151
2000-Dec	1617358	174.6	39131600	5151
2001-Jan	1619755	175.6	35842500	5151
2001-Feb	1622152	176.0	42152200	5151
2001-Mar	1621539	176.1	41934900	5151
2001-Apr	1620926	176.6	50898800	5151
2001-May	1620313	177.4	40642100	5151
2001-Jun	1626856	177.8	40702300	5151
2001-Jul	1633400	177.4	53306200	5151
2001-Aug	1639943	177.5	43197200	5257
2001-Sep	1636352	178.1	51497000	5257
2001-Oct	1632762	177.5	40134100	5277
2001-Nov	1629171	177.5	40944300	5277
2001-Dec	1632542	177.3	45388200	5277

	Income	CPI-U	Revenues	Machines
2002-Jan	1635914	177.7	39979900	5277
2002-Feb	1639285	177.9	46968200	5277
2002-Mar	1642600	178.6	56159100	5277
2002-Apr	1645916	179.4	47009700	5277
2002-May	1649231	179.5	44781900	5277
2002-Jun	1648481	179.6	56111400	5327
2002-Jul	1647732	180.0	46438700	5327
2002-Aug	1646982	180.5	45902500	5314
2002-Sep	1646597	180.8	57002000	5428
2002-Oct	1646211	181.1	42924300	5430
2002-Nov	1645826	181.4	42415300	5430
2002-Dec	1650956	181.6	40216900	5430
2003-Jan	1656087	182.3	36836100	5430
2003-Feb	1661217	183.3	33859500	5430
2003-Mar	1668567	184.1	49735600	5430
2003-Apr	1675918	183.5	38954200	5430
2003-May	1683268	183.3	40114300	5430
2003-Jun	1689123	183.4	50064600	5430
2003-Jul	1694978	183.8	42487200	5432
2003-Aug	1700833	184.4	53649700	5435
2003-Sep	1708116	185.0	38688200	5442
2003-Oct	1715399	184.8	38862800	5456
2003-Nov	1722682	184.6	47178800	5524
2003-Dec	1730536	185.0	31568700	5683
2004-Jan	1738391	185.9	39550300	5760
2004-Feb	1746245	186.5	53664900	6143
2004-Mar	1753068	187.3	44572800	6345
2004-Apr	1759892	187.7	43115200	6410
2004-May	1766715	188.8	53316400	6410
2004-Jun	1775502	189.3	43315900	6410
2004-Jul	1784289	189.2	45887600	6410
2004-Aug	1793076	189.3	55295000	6410
2004-Sep	1806554	189.6	44245600	6435
2004-Oct	1820032	190.7	53780700	6435
2004-Nov	1833510	191.2	41645700	6435
2004-Dec	1846988	191.2	34928600	6435